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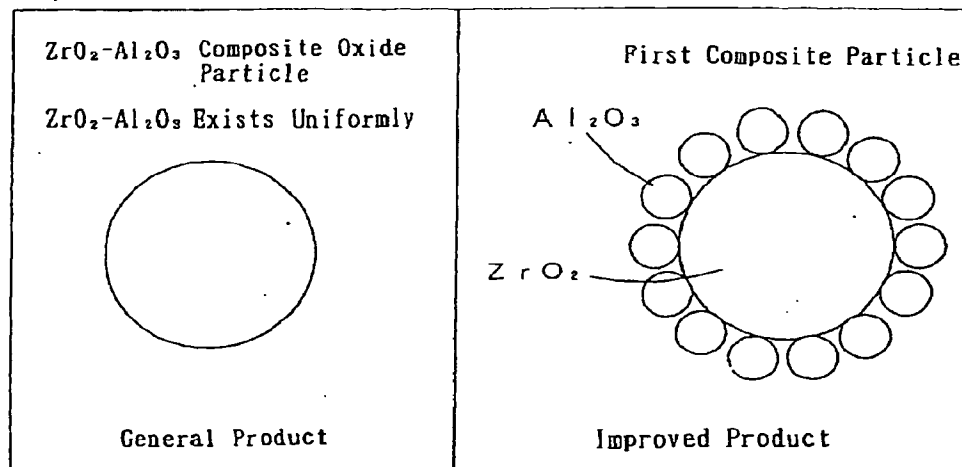
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(54) **CATALYST FOR HYDROGEN GENERATION AND CATALYST FOR PURIFICATION OF EXHAUST GAS**

(57) An NO_x sorption-and-reduction type catalyst is made which includes a hydrogen generating catalyst in which Rh is loaded on a support including an Al₂O₃-ZrO₂ composite oxide. Since the Al₂O₃-ZrO₂ composite oxide exhibits a basicity lower than ZrO₂, SO_x are less likely to approach so that it is possible to suppress the sulfur

poisoning of Rh. Moreover, the Al₂O₃-ZrO₂ composite oxide exhibits higher heat resistance than ZrO₂, and it has a function of improving the steam reforming reaction activity of Rh in the same manner as ZrO₂. Therefore, the post-durability NO_x purifying ability of the NO_x sorption-and-reduction type catalyst is improved.

FIG. 1



Description

Technical Field

[0001] The present invention relates to a hydrogen generating catalyst which generates hydrogen out of hydrocarbons in an exhaust gas which is put in a rich atmosphere in short of oxygen, and an NO_x sorption-and-reduction type catalyst for purifying an exhaust gas which utilizes this hydrogen generating catalyst.

Background Art

[0002] Recently, as a catalyst for purifying NO_x in an exhaust gas of an oxygen-excessive lean atmosphere, an NO_x sorption-and-reduction type catalyst has been utilized. This NO_x sorption-and-reduction type catalyst, for example, as disclosed in Japanese Unexamined Patent Publication (KOKAI) No. 5-317,625, is one in which a noble metal, such as Pt and Rh, and an NO_x sorption member, such as K and Ba, are loaded on a porous support, such as Al₂O₃. By using this NO_x sorption-and-reduction type catalyst and controlling an air-fuel ratio from a lean side to a stoichiometric as well as rich side in a pulsating manner (rich spiking), since an exhaust gas, too, becomes from a lean atmosphere to a stoichiometric as well as rich atmosphere, NO_x are sorbed in the NO_x sorption member on the lean side, and they are released on the stoichiometric or rich side to react with reductive components, such as HC and CO, so that they are purified. Therefore, even when it is an exhaust gas from a lean burn engine, it is possible to purify NO_x with good efficiency. Moreover, since HC and CO in the exhaust gas are oxidized by the noble metal and, at the same time, are consumed in the reduction of NO_x, HC as well as CO are also purified with good efficiency.

[0003] For example, in Japanese Unexamined Patent Publication (KOKAI) No. 5-317,652, a catalyst for purifying an exhaust gas is proposed in which an alkaline-earth metal, such as Ba, and Pt are loaded on a porous oxide support, such as Al₂O₃. Further, in Japanese Unexamined Patent Publication (KOKAI) No. 6-31, 139, a catalyst for purifying an exhaust gas is proposed in which an alkali metal, such as K, and Pt are loaded on a porous oxide support, such as Al₂O₃. Furthermore, in Japanese Unexamined Patent Publication (KOKAI) No. 5-168,860, a catalyst for purifying an exhaust gas is proposed in which a rare-earth element, such as La, and Pt are loaded on a porous oxide support, such as Al₂O₃.

[0004] It has been found out that the purifying reaction of NO_x in the NO_x sorption-and-reduction type catalyst comprises a first step, in which NO in an exhaust gas is oxidized to make it into NO_x, a second step, in which NO_x are sorbed onto an NO_x sorption member, and a third step, in which NO_x released from the NO_x sorption member are reduced on the catalyst.

[0005] However, in the conventional NO_x sorption-and-reduction type catalyst, the granular growth of Pt occurs in a lean atmosphere, there is a problem in that the reactivities of the aforementioned first step and second step are lowered by the decrement in the catalytic active sites.

[0006] While, as a catalytic noble metal which is less likely cause such a granular growth in a lean atmosphere, Rh has been known, however, the oxidizing ability does not come up to Pt. Hence, it is thought of using Pt and Rh together.

[0007] However, when Pt and Rh are used together, there is a drawback in that the oxidizing ability of Pt lowers. Accordingly, as the addition amount of Rh increases, the reactivity of the first step, in which NO is oxidized to make it into NO_x, lowers so that the sorbing ability of NO_x in the second step lowers as well. Moreover, Rh is poor in terms of the compatibility to an NO_x sorption member, and there is a problem in that, when Rh and an NO_x sorption member coexist, the characteristics of the NO_x sorption ability and Rh cannot be fully exhibited.

[0008] Moreover, in an exhaust gas, SO₂, which is generated by burning sulfur (S) contained in a fuel, is included, and it is oxidized by a noble metal in an exhaust gas of a lean atmosphere so that it is turned into SO₃. Then, it has become apparent that it is readily turned into sulfuric acid by water vapor, which is also contained in the exhaust gas, that these react with the NO_x sorption member to generate sulfites and sulfates, and that the NO_x sorption member is thereby poisoned to degrade. This is referred to as the sulfur poisoning of the NO_x sorption member. In addition, since the porous oxide support, such as Al₂O₃, has a property that it is likely to adsorb SO_x, there is a problem in that the aforementioned sulfur poisoning has been facilitated. Then, when the NO_x sorption member is thus turned into sulfites and sulfates so that it is poisoned to degrade, it can no longer sorb NO_x, as a result, there is a drawback in that the NO_x purifying performance lowers after a high-temperature durability test (hereinafter, referred to as "post-durability").

[0009] Hence, in Japanese Unexamined Patent Publication (KOKAI) No. 10-356, there is disclosed an NO_x sorption-and-reduction type catalyst which is made by intermingling a first powder, in which Rh is loaded on Al₂O₃ or ZrO₂, and a second powder, in which an NO_x sorption member and Pt are loaded on Al₂O₃. In accordance with this NO_x sorption-and-reduction type catalyst, since Rh and Pt are loaded separately, the oxidizing ability of Pt is inhibited from lowering. Moreover, since Rh and the NO_x sorption member are loaded separately, the pooriness in the mutual compatibility is not revealed so that the characteristics of the NO_x sorption member and Rh are fully exhibited.

[0010] Moreover, in accordance with ZrO₂ with Rh loaded (hereinafter referred to as an "Rh/ZrO₂ catalyst"), hydrogen

having a high reducing power is formed out of HC and H₂O in an exhaust gas (a steam reforming reaction), and this hydrogen contributes to the reduction of NO_x and the elimination of SO_x from sulfates of the NO_x sorption member. Thus, the NO_x reduction ability in rich spiking becomes high, and the sulfur poisoning becomes remarkably less.

[0011] However, compared with Al₂O₃ which is often used as a support for noble metals, ZrO₂ exhibits lower heat resistance, the specific surface area is decreased by the heat in service, and thereby there is a drawback in that the dispersibility of Rh lowers so that the hydrogen generating ability lowers. Moreover, since ZrO₂ is a basic support, SO_x in an exhaust gas are likely to approach, and accordingly a phenomenon arises in which the hydrogen generating ability is lowered by the sulfur poisoning of loaded Rh.

[0012] Accordingly, in an NO_x sorption-and-reduction type catalyst including an Rh/ZrO₂ catalyst, there is a problem in that the post-durability NO_x purifying ability is lowered by the lowering of the hydrogen generating ability of the Rh/ZrO₂ catalyst.

[0013] Moreover, it has been understood that another cause, by which the post-durability NO_x purifying ability is lowered, lies in that a reaction occurs between cordierite, which has been used as a support substrate in general, and an alkali component, which works as the NO_x sorption member, and thereby the NO_x sorption ability has been lowered.

[0014] Namely, the alkali component is likely to move in a coating layer, such as Al₂O₃, and simultaneously exhibits a high reactivity to Si. Accordingly, it is believed that the alkali component moves in the coating layer when the temperature is high, arrives at the support substrate and reacts with Si in cordierite to form silicate, being a composite oxide. Since this silicate is a stable compound, the alkali component, which has been turned into silicate, no longer has an ability of sorbing NO_x, and accordingly the NO_x purifying performance has been lowered.

[0015] Hence, in Japanese Unexamined Patent Publication (KOKAI) No. 8-117,602, an NO_x sorption-and-reduction type catalyst is proposed in which a Ti-Zr composite oxide, an NO_x sorption member and a noble metal are loaded on an Al₂O₃ support.

[0016] By thus making a composite support in which a Ti-Zr composite oxide is loaded on Al₂O₃, it is possible to highly maintain the initial NO_x purifying rate due to the advantage of Al₂O₃. Moreover, by loading a Ti-Zr composite oxide, it is possible to raise the acidity of the support itself. Therefore, since this composite support, compared with the case where Al₂O₃ is used alone, is less likely to adsorb SO_x, and since adsorbed SO_x are likely to eliminate at a low temperature, the contacting probability between the NO_x sorption member and SO_x is lowered. In addition, in a support in which a Ti-Zr composite oxide is loaded, it is believed that the movement of alkali component is suppressed, and it has been understood that the reaction of the alkali component to TiO₂ is suppressed. Therefore, when the aforementioned composite support is used, a high NO_x purifying rate is secured even in the initial period, since the sulfur poisoning as well as the solving of the alkali metal into the support are suppressed, a post-durability NO_x purifying rate is improved.

[0017] However, in a catalyst in which a Ti-Zr composite oxide is loaded on an Al₂O₃ support, compared with a composite support comprising TiO₂-Al₂O₃ as disclosed in Japanese Unexamined Patent Publication (KOKAI) No. 8-099, 034 or a catalyst which uses a support in which TiO₂ is added to Al₂O₃, it is not possible to say that the suppression effect of the sulfur poisoning is sufficient, and accordingly it has been required to further suppress the sulfur poisoning and improve the NO_x purifying rate.

[0018] Moreover, due to the recent improvement of engine performance, the increase of high speed driving, and the like, the temperature of exhaust gas has risen so that the improvement of NO_x purifying activity in a high temperature region has become an assignment. This is because, in a high temperature region, NO_x, which have been sorbed in an NO_x sorption member, are likely to be released, and the NO_x sorption amount is likely to be insufficient in a lean atmosphere. Hence, K, which exhibits a high basicity and is stable at a high temperature, is made into an NO_x sorption member, but, in a catalyst in which K is loaded on Al₂O₃, and so on, there has been a problem in that the NO_x sorption ability in a high temperature region is not improved so much.

[0019] Hence, it was thought of using a support which exhibits a higher basicity, and, in Japanese Unexamined Patent Publication (KOKAI) No. 5-195, 755, a catalyst is disclosed in which K and a noble metal are loaded on ZrO₂. In accordance with this catalyst, since the basicities of the support and NO_x sorption member are high, it is likely to sorb but less likely to release NO_x. Therefore, the NO_x sorption ability in a high temperature region is improved, as a result, the NO_x purifying performance in a high temperature region is improved.

[0020] However, in the catalyst in which K and a noble metal are loaded on ZrO₂, since the basicity of the support is high, there has been a drawback in that it is likely to sorb not only NO_x but also SO_x so that the lowering of the activity by the sulfur poisoning is considerable. Namely, when the basicity of a support is high, although the NO_x sorption ability is improved, even the sulfur poisoning is facilitated. On the contrary, when the basicity of a support is low, although the sulfur poisoning is suppressed, even the NO_x sorption ability is lowered.

[0021] The present invention has been done in view of such circumstances, it is a main object to improve the heat resistance and sulfur-poisoning resistance of an Rh/ZrO₂ catalyst, being a hydrogen generating catalyst, and, being accompanied therewith, to improve the post-durability NO_x purifying ability of an NO_x sorption-and-reduction type catalyst.

[0022] Moreover, the second object of the present invention is to further suppress the sulfur poisoning of an NO_x sorption-and-reduction type catalyst, thereby furthermore improving the high-temperature post-durability NO_x purifying rate.

[0023] In addition, a further object of the present invention is to make a catalyst which can satisfy both of the contradictory phenomena, such as the improvement of the NO_x sorption ability in a high temperature region and the suppression of the sulfur poisoning, and which is good in terms of the heat resistance.

[0024] The characteristic of a hydrogen generating catalyst, which solves the aforementioned assignments and is set forth in claim 1, lies in that Rh is loaded on a support comprising a ZrO₂-Al₂O₃ composite oxide.

[0025] Al₂O₃ can desirably be included in an amount of from 1 to 30% by mol in the ZrO₂-Al₂O₃ composite oxide. Moreover, the support comprising the ZrO₂-Al₂O₃ composite oxide can desirably include first composite particles having a structure comprising a core portion in which ZrO₂ is a major component and a superficial portion formed on a surface of the core portion and including Al₂O₃ more than the core portion.

[0026] Then, the characteristic of a catalyst for purifying an exhaust gas, of an NO_x sorption-and-reduction type catalyst comprising a noble metal and an NO_x sorption member loaded on a porous oxide support, which solves the aforementioned assignments and is set forth in claim 4, lies in that the hydrogen generating catalyst of the present invention is included. The porous oxide support can desirably include second composite particles having a structure comprising a core portion in which ZrO₂ is a major component and a superficial portion formed on a surface of the core portion and including an oxide, whose basicity is lower than ZrO₂, more than the core portion.

Brief Description of Drawings

[0027] Fig. 1 is an explanatory diagram for schematically illustrating the structures of a general ZrO₂-Al₂O₃ composite oxide particle and a first composite particle which is its improved product.

[0028] Fig. 2 is an explanatory diagram for schematically illustrating the structure of second composite particles which comprise a ZrO₂-TiO₂ composite oxide.

[0029] Fig. 3 is a graph for illustrating the relationships between the temperatures and hydrogen generation amounts in the hydrogen generating catalysts of examples as well as a comparative example.

[0030] Fig. 4 is a graph for illustrating the relationships between the temperatures and saturated NO_x sorption amounts in the NO_x sorption-and-reduction type catalysts of an example as well as comparative examples.

[0031] Fig. 5 is a graph for illustrating the fed compositions and superficial compositions of ZrO₂-Al₂O₃ composite particles which were manufactured in a testing example.

[0032] Fig. 6 is a graph for illustrating the relationships between the temperatures and post-rich-spiking NO_x sorption amounts in the catalysts of an example as well as comparative examples.

Best Mode for Carrying out Invention

[0033] In the hydrogen generating catalyst of the present invention, Rh is loaded on a support comprising a ZrO₂-Al₂O₃ composite oxide. Since the ZrO₂-Al₂O₃ composite oxide exhibits a lower basicity than ZrO₂, SO_x become less likely to approach so that it is possible to suppress the sulfur poisoning of Rh. Moreover, the ZrO₂-Al₂O₃ composite oxide exhibits higher heat resistance than ZrO₂. Then, similarly to ZrO₂, the ZrO₂-Al₂O₃ composite oxide has the function of improving the steam reforming reaction activity of Rh.

[0034] Therefore, in accordance with the hydrogen generating catalyst of the present invention in which Rh is loaded on a support comprising a ZrO₂-Al₂O₃ composite oxide, compared with an Rh/ZrO₂ catalyst, the heat resistance and sulfur-poisoning resistance are improved, and accordingly a high hydrogen generating ability is revealed even in post-durability.

[0035] Moreover, in accordance with the catalyst for purifying an exhaust gas of the present invention, since the hydrogen generating catalyst of the present invention is included, it is good in terms of the hydrogen generating ability from initial period to post-durability, and thereby a high NO_x purifying ability is revealed from initial period to post-durability.

[0036] In the hydrogen generating catalyst of the present invention, the Al₂O₃ amount in the ZrO₂-Al₂O₃ composite oxide can desirably be from 1 to 30% by mol. When Al₂O₃ is less than 1% by mol, the effect of the improvement of the heat resistance and sulfur-poisoning resistance cannot be obtained so that the post-durability hydrogen generating ability is lowered, when Al₂O₃ is more than 30% by mol, the hydrogen generating ability is lowered even from initial period.

[0037] The support comprising the ZrO₂-Al₂O₃ composite oxide can desirably include first composite particles, which have a structure comprising a core portion in which ZrO₂ is a major component and a superficial portion formed on a surface of the core portion and including Al₂O₃ more than the core portion. The first composite particles exhibit a high basicity at the inside by the core portion in which ZrO₂ is a major component, and exhibit a low basicity at the superficial

portion by Al_2O_3 which exists more in the superficial portion. Consequently, it is believed SO_x are inhibited from approaching, and accordingly the hydrogen generating catalyst of the present invention is improved in terms of the sulfur-poisoning resistance. Moreover, similarly to a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide having a uniform composition, it has the function of improving the steam reforming reaction activity of Rh.

[0038] A general $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide particle, as illustrated as "General Product" in Fig. 1, is made into a uniform composition from the surface to the inside. However, the first composite particle which is used in the present invention, as illustrated as "Improved Product" in Fig. 1, is made into a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion. The Al_2O_3 in the superficial portion can be formed as a fine particle shape or a film shape, but ZrO_2 can desirably be exposed partially. Moreover, the Al_2O_3 in the superficial portion can desirably exist in a highly dispersed state.

[0039] Note that, although both of the particles illustrated in Fig. 1 are a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide each, in order to distinguish them, the composite oxide particle, whose structure comprises a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion, is referred to as a first composite particle, and the composite oxide particle, whose structure is uniform from the inside to the surface, is referred to as a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide particle. In order to manufacture the first composite particles, for instance, zirconia precursors are precipitated out of a zirconium salt aqueous solution by pH adjustment, and they are calcined to make a ZrO_2 powder. To a suspension, in which this ZrO_2 powder is mixed in water, an aluminum salt aqueous solution is added, and alumina precursors are precipitated on the surface of the ZrO_2 powder by further carrying out pH adjustment. Thereafter, by calcining the resulting deposits, it is possible to manufacture the first composite particles whose structure comprises a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion.

[0040] It is desirable to use the first composite particles, whose structure comprises a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion, having an average particle diameter of $10\text{ }\mu\text{m}$ or less. With such an arrangement, it is believed that, in the first composite particles in proximity with each other, the probability of contacting the Al_2O_3 with each other or the ZrO_2 with each other lowers, and it is believed that the different members become partition walls so that the sintering is suppressed. Accordingly, the heat resistance is improved, and it is possible to suppress the lowering of the post-durability specific surface area.

[0041] Moreover, similarly to an Rh/ ZrO_2 catalyst, the loading amount of Rh in the hydrogen generating catalyst of the present invention can preferably be from 0.01 to 10% by weight, and is especially preferable to fall in a range of from 0.5 to 2% by weight. When the loading amount of Rh is less than 0.01% by weight, the hydrogen generating ability is not revealed, and, when it is loaded in an amount of more than 10% by weight, not only the hydrogen generating ability saturates but also the costs go up.

[0042] Then, the catalyst for purifying an exhaust gas of the present invention, in an NO_x sorption-and-reduction type catalyst in which a noble metal and an NO_x sorption member are loaded on a porous oxide support, includes the hydrogen generating catalyst of the present invention. Since, compared with an Rh/ ZrO_2 catalyst, the hydrogen generating catalyst of the present invention is improved in terms of the heat resistance and sulfur-poisoning resistance, a high hydrogen generating ability is revealed even in post-durability, and the catalyst for purifying an exhaust gas of the present invention is good in terms of the post-durability NO_x purifying ability. Moreover, in the catalyst for purifying an exhaust gas of the present invention, Pt and Rh can be loaded separately so that it is possible to suppress the lowering in the oxidizing ability of Pt due to Rh. In addition, since it is possible to separately load Rh and the NO_x sorption member, the poorness in the mutual compatibility is not revealed, and accordingly the characteristics of the NO_x sorption member and Rh are fully exhibited.

[0043] Concerning the content of the hydrogen generating catalyst in the catalyst for purifying an exhaust gas of the present invention, when it is included in a small amount, the NO_x purifying ability is improved to that extent, however, it is preferable to make the upper limit 50% by weight. When the amount of the hydrogen generating catalyst is more than this, it is not preferable because the content of the NO_x sorption-and-reduction type catalyst decreases relatively so that the NO_x sorption ability lowers. Note that, in order to contain the hydrogen generating catalyst, although the hydrogen generating catalyst of the present invention can be loaded on a porous support oxide support along with a noble metal and an NO_x sorption member, it is preferable to use a mixture powder of a powder of an NO_x sorption-and-reduction type catalyst, which comprises a noble metal and an NO_x sorption member loaded on a porous support, and a powder of the hydrogen generating catalyst of the present invention.

[0044] As a porous oxide support of the NO_x sorption-and-reduction type catalyst, it is possible to use Al_2O_3 , TiO_2 , SiO_2 or ZrO_2 , or an arbitrary composite oxide selected from them. For example, when a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide is used as the porous oxide support, and when an alkali metal, such as K, is loaded as the NO_x sorption member, it is especially preferred because it is not only good in terms of the NO_x sorption ability in a high temperature region but also the sulfur-poisoning resistance is improved. Namely, since a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide exhibits a lower basicity

than ZrO_2 , it is possible to suppress the sulfur poisoning of NO_x sorption member. Moreover, in this case, since it is possible to use the same support as the hydrogen generating catalyst, it is possible to reduce the number of raw materials, and accordingly it is possible to reduce the man-hour requirements for manufacturing.

[0045] The porous oxide support of the NO_x sorption-and-reduction type catalyst can desirably include second composite particles having a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including an oxide, whose basicity is lower than ZrO_2 , more than the core portion. With such an arrangement, since the basicity of the superficial portion is low, SO_x are less likely to approach so that the sulfurpoisoning of NO_x sorptionmember is further suppressed. As an oxide whose basicity is lower than ZrO_2 , Al_2O_3 , TiO_2 , SiO_2 , and the like, are exemplified. For example, in second composite particles having a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion, the basicity of the inside is high because of the core portion in which ZrO_2 is a major component, and the basicity of the superficial portion is low because of Al_2O_3 which exists more on the surface of the core portion than the core portion. Accordingly, not only the sulfur-poisoning resistance is improved, but also the NO_x sorption ability in a high temperature region is improved though the reason is not clear.

[0046] The second composite particles, which have a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion, are the ones similar to the above-described first composite particles, and accordingly it is possible to manufacture in the same manner as the above-described first composite particles. It is preferred that a composition of the second composite particles can fall in a range of $\text{Al}_2\text{O}_3/\text{ZrO}_2 = 3/97 - 15/85$ by molar ratio for the entire particles. When the ZrO_2 is less than this range, the NO_x sorption ability in a high temperature region lowers, when the ZrO_2 is more than this range, the sulfur-poisoning resistance and heat resistance lower.

[0047] Moreover, it is desirable to use the second composite particles, whose structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion, having an average particle diameter of 10 μm or less. With such an arrangement, it is believed that, in the second composite particles in proximity with each other, the probability of contacting the Al_2O_3 with each other or the ZrO_2 with each other lowers, and it is believed that the different members become partition walls so that the sintering is suppressed. Accordingly, the heat resistance is improved, and it is possible to suppress the lowering of the post-durability specific surface area.

[0048] By the way, in an NO_x sorption-and-reduction type catalyst which uses a support in which a Ti-Zr composite oxide is loaded on an Al_2O_3 support, the cause that the action of suppressing the sulfur poisoning is not improved so much as expected is believed to lie in that, since the Ti and Zr are dispersed uniformly in the Ti-Zr composite oxide, the inside TiO_2 does not function effectively.

[0049] Hence, as the oxide whose basicity is lower than ZrO_2 , it is also preferable to select TiO_2 , and to use second composite particles whose structure comprises a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion. In the second composite particles, since the TiO_2 is included more in the surface, the utility efficiency of TiO_2 is improved. Then, since TiO_2 has less basic sites so that SO_x are less likely to adsorb thereto, or so that adsorbed SO_x are likely to eliminate therefrom, all in all, the adsorption amount of SO_x is reduced. Moreover, due to the reasons that the contacting interface between the NO_x sorption member and TiO_2 increases, and that composite oxide precursors, which are likely to decompose, are thereby formed, adsorbed SO_x are eliminated with ease. By these actions, the suppression action of sulfur poisoning is improved. In addition, in the second composite particles, similarly to a Ti-Zr composite oxide, the movement of an alkali component is suppressed, and accordingly the reaction between the alkali component and TiO_2 is also suppressed.

[0050] The second composite particles, whose structure comprises a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion, are formed as a dual structure as illustrated in Fig. 2. In the second composite particles, it is desirable to include TiO_2 in an amount of 30% by weight or more in the superficial portion. When the TiO_2 in the superficial portion is less than 30% by weight, the sulfur-poisoning-suppression action lowers. Note that, it has been found out that, even when the TiO_2 in the superficial portion is too much, the sulfur-poisoning-suppression effect lowers, and accordingly it is desirable to make the TiO_2 in the superficial portion less than 80% by weight.

[0051] Moreover, it is desired that the second composite particles, whose structure comprises a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion, can be particles having a particle diameter of 10 μm or less. When the particle diameter exceeds 10 μm , since the surface area of TiO_2 , which contacts with sulfur components, becomes too small so that the sulfur-poisoning-suppression action lowers. Then, since the smaller the particle diameter is the higher the superficial-portion-occupying rate is, when the particle diameter is 10 μm or less, it is easy for the TiO_2 in the superficial portion to occupy 30% by weight or more. In addition, it is believed that, in the composite particles in proximity with each other, the

probability of contacting the TiO_2 with each other or the ZrO_2 with each other lowers, and it is believed that the different members become partition walls so that the sintering is suppressed. Accordingly, the heat resistance is improved, and it is possible to suppress the lowering of the post-durability specific surface area.

[0052] In the second composite particles whose structure comprises a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion, it is desirable to further include Al_2O_3 . By including Al_2O_3 , the heat resistance is improved, and it is possible to suppress the lowering of the high-temperature post-durability specific surface area, at the same time, it is possible to suppress the granular growth of noble metal accompanied therewith, and the durability is improved. The Al_2O_3 can be included in at least one of the core portion and superficial portion, and is ordinarily included in both of the core portion and superficial portion.

[0053] It is desired that the Al_2O_3 can be included in an amount of 10% by mol or more. When it is less than 10% by mol, it is difficult to reveal the adding effect. Although the more the content of Al_2O_3 is the larger the high-temperature post-durability specific surface area is, since the amount of TiO_2 decreases relatively, it is preferable to make the amount of Al_2O_3 in a range of 50% by mol or less.

[0054] In order to manufacture the second composite particles whose structure comprises a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion, for instance, zirconia precursors are precipitated out of a zirconium salt aqueous solution by pH adjustment, and they are calcined to make a ZrO_2 powder. To a suspension, in which this ZrO_2 powder is mixed in water, a titanium salt aqueous solution is added, and titania precursors are precipitated on the surface of the ZrO_2 powder by further carrying out pH adjustment. Thereafter, by calcining the resulting deposits, it is possible to manufacture the second composite oxide particles whose structure comprises a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion. Moreover, in order to further include Al_2O_3 , an aluminum salt can be solved in one of the zirconium salt and titanium salt aqueous solutions or both of the aqueous solutions.

[0055] The catalyst for purifying an exhaust gas of the present invention can be formed as a shape, such as a pellet shape, a honeycomb shape or a foam shape, similarly to the conventional catalysts for purifying an exhaust gas. For example, in order to form it as a pellet shape, it can be molded into a pellet shape out of a mixture powder of a powder of an NO_x sorption-and-reduction type catalyst and a powder of the hydrogen generating catalyst of the present invention. Moreover, it is possible to manufacture it by forming a coating layer on a support substrate out of a mixture powder in which a powder of an NO_x sorption-and-reduction type catalyst and a powder of the hydrogen generating catalyst of the present invention are mixed. Alternatively, it is possible to manufacture it by forming a coating layer on a support substrate out of the aforementioned various porous oxide powders and loading the hydrogen generating catalyst, a noble metal and an NO_x sorption member on the coating layer. In addition, a coating layer can be formed out of a porous oxide powder and a powder of the hydrogen generating catalyst, and a noble metal and an NO_x sorption member can be loaded on the coating layer.

[0056] As the support substrate, it is possible to use one which is formed of heat resistant ceramics, such as cordierite, or a metal, and its shape can be selected from the group consisting of a honeycomb-shaped monolithic type, foam type, pellet type, and so on.

[0057] It is possible to form the coating layer by a general wash coating method. As a binder in this case, it is possible to use an alumina sol or a zirconia sol, and the like. Further, in the coating layer, it is desirable to include at least one optimum porous oxide powder selected from the group consisting of a ZrO_2 - Al_2O_3 composite oxide powder, a powder comprising second composite particles which have a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion, a powder comprising second composite particles which have a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion, or a powder comprising particles further including Al_2O_3 in addition to the latter second composite particles. Furthermore, in addition to these, it can further include an arbitrary porous oxide powder, such as Al_2O_3 , SiO_2 , ZrO_2 , TiO_2 and CeO_2 . Moreover, it is possible to make an arrangement in which at least one powder selected from the group consisting of the aforementioned optimum porous oxide powders is loaded on a coating layer which comprises a porous oxide, such as Al_2O_3 , SiO_2 , ZrO_2 , TiO_2 and CeO_2 . In a case where an arbitrary porous oxide powder coexists, it is desirable to use the optimum porous oxide powders in an amount of 20% by weight or more at least. When the optimum porous oxide powders are less than this, it is difficult to reveal the effects of the improvement of the sulfur-poisoning resistance as well as the improvement of the NO_x sorption ability in a high temperature region.

[0058] It is preferable to form the coating layer in a range of from 150 to 500 g with respect to 1 liter of a support substrate. When the forming amount of the coating layer is less than this, since the loading densities of the noble metal and NO_x sorption member heighten, the durability of the purifying performance lowers, when it is formed more than this, such a drawback arises that the ventilation resistance enlarges.

[0059] As the noble metal loaded on the coating layer, it is possible to use one or more members of Pt, Rh, Pd, Ir or

Ru. Moreover, as the NO_x sorption member, it is possible to use at least one member selected from the group consisting of alkali metals, alkaline-earth metals and rare-earth elements. Among them, it is preferable to use at least one of alkali metals and alkaline-earth metals which exhibit a high alkalinity and a high NO_x sorption ability.

[0060] As the alkalimetal, Li, Na, K, Cs, and the like, are exemplified. The alkaline-earth metals refer to the 2A group elements in the periodic table of the elements, and Ba, Be, Mg, Ca, Sr, and so on, are exemplified. Moreover, as the rare-earth element, Sc, Y, La, Ce, Pr, Nd, Dy, Yb, and the like, are exemplified.

[0061] The loading amount of the noble metal on the coating layer, in the case of Pt and Pd, can preferably be from 0.1 to 10 g, especially preferably from 0.5 to 10 g, with respect to 1 liter of a support substrate. Further, in the case of Rh, it can preferably be from 0.01 to 10 g, especially preferably from 0.05 to 5 g. Furthermore, the loading amount of the NO_x sorption member can desirably fall in a range of from 0.05 to 1.0 mol with respect to 1 liter of a support substrate. When the loading amount of the NO_x sorption member is less than 0.05 mol/L, the NO_x sorption ability lowers, when it is more than 1.0 mol/L, the sintering of noble metal is promoted.

[0062] A noble metal, excepting Rh, and an NO_x sorption member can desirably be loaded on an optimum porous oxide powder which is selected from the group consisting of a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide powder, a powder comprising second composite particles which have a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion, a powder comprising second composite particles which have a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion, or a powder comprising particles further including Al_2O_3 in addition to the latter second composite particles. With such an arrangement, since Pt and Rh are inhibited from being loaded in proximity with each other, and since it is possible to inhibit Rh and an NO_x sorption member from being loaded in proximity with each other, the purifying activity is further improved.

[0063] Then, by using the aforementioned catalyst for purifying an exhaust gas of the present invention, an oxygen-excessive-atmosphere exhaust gas, which has been burned at an air-fuel ratio (A/F) of about 18 or more, is contacted therewith so that NO_x , which are contained in the exhaust gas, are sorbed in the NO_x sorption member, and the air-fuel ratio is fluctuated intermittently to be stoichiometric as well as oxygen-excessive so that NO_x , which have been released from the NO_x sorption member, are reduced and purified. In an oxygen-excessive atmosphere, NO, which is contained in an exhaust gas, is oxidized on the catalyst to be turned into NO_x , and it is sorbed in the NO_x sorption member. Then, when being put into a stoichiometric as well as oxygen-excessive atmosphere, NO_x are released from the NO_x sorption member, and they react with HC and CO, which are contained in the exhaust gas, on the catalyst so that they are reduced.

[0064] Then, when at least one of the first composite particles and the second composite particles are included, SO_x are less likely to be adsorbed so that the sulfur poisoning of the NO_x sorption member is suppressed. Moreover, when the second composite particles, which have a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion, are included, due to such reasons that the interface between the TiO_2 and NO_x sorption member enlarges, and that composite oxide precursors, which are likely to decompose, are thereby formed, it is believed that the elimination of adsorbed SO_x becomes more readily, accordingly it is possible to fully suppress the sulfur poisoning of the NO_x sorption member even in post-durability, and it is possible to fully suppress the lowering of the NO_x purifying ability.

[0065] Namely, in accordance with the hydrogen generating catalyst of the present invention, not only since it exhibits a hydrogen generating ability equivalent to an Rh/ ZrO_2 catalyst, but also it is good in terms of the heat resistance and sulfur-poisoning resistance, a high hydrogen generating ability is revealed even in post-durability.

[0066] Then, in accordance with the catalyst for purifying an exhaust gas of the present invention, since it includes the hydrogen generated catalyst of the present invention, not only it is possible to inhibit the sulfur poisoning of the NO_x sorption member by generated hydrogen, but also it is possible to maintain the characteristics even in high-temperature post-durability. Moreover, when an NO_x sorption-and-reduction type catalyst is used in which a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide is made into a support, since the sulfur poisoning is suppressed to a higher extent, the durability is improved so that it is possible to more stably purify NO_x . Then, when an NO_x sorption-and-reduction type catalyst is used in which second composite particles are made into a support, the sulfur-poisoning resistance is further improved so that a much higher NO_x purifying ability is revealed even in post-durability.

Examples

[0067] Hereinafter, the present invention will be described in detail with reference to examples and comparative examples.

(Example No. 1)

[0068] With respect to a predetermined amount of a commercially available $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid-solution powder which included Al_2O_3 in an amount of 1% by mol, a rhodium nitrate aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was dried at 250°C for 15 minutes, and was thereafter calcined at 500 °C for 30 minutes to load Rh. The loading amount of Rh was 1.0% by weight. The resulting catalyst was formed as a pellet shape of about 2 mm by an ordinary method, thereby preparing a pellet catalyst.

(Example No. 2)

[0069] Except that a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid-solution powder was used which included Al_2O_3 in an amount of 10% by mol, a pellet catalyst of Example No. 2 was prepared in the same manner as Example No. 1.

(Example No. 3)

[0070] Except that a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid-solution powder was used which included Al_2O_3 in an amount of 20% by mol, a pellet catalyst of Example No. 3 was prepared in the same manner as Example No. 1.

(Example No. 4)

[0071] Except that a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid-solution powder was used which included Al_2O_3 in an amount of 30% by mol, a pellet catalyst of Example No. 4 was prepared in the same manner as Example No. 1.

(Comparative Example No. 1)

[0072] Except that a ZrO_2 powder was used instead of the $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid-solution powder, a pellet catalyst of Comparative Example No. 1 was prepared in the same manner as Example No. 1.

<Testing and Evaluation>

[0073] The respective catalysts of the examples and comparative example were put in an evaluating apparatus, and a durability test was carried out in which they were held at 550 °C for 3 hours in a fluctuating atmosphere in which the lean/rich model gases set forth in Table 1 were flowed for 4-minute rich model gas and for 1-minute lean gas. The total flow rate of the gases was 30 L/min.

TABLE 1

	H ₂ %	NO ppm	C ₃ H ₆ ppmC	CO ₂ %	CO %	O ₂ %	SO ₂ ppm	N ₂
Lean	none	400	2500	9.5	0.1	7.0	100	balance
Rich	2.0	400	3200	12	6.0	none	100	balance

[0074] On the respective pellet catalysts after the durability test, the hydrogen generation amounts were measured at the respective temperatures, 300°C, 400°C, 500°C and 600 °C, by using a rich model gas set forth in Table 2. The results are illustrated in Fig. 3.

TABLE 2

	H ₂ %	NO ppm	C ₃ H ₆ ppmC	CO ₂ %	CO %	O ₂ %	SO ₂ ppm	N ₂
Rich	10	none	3200	none	none	none	none	balance

[0075] From Fig. 3, it is seen that, compared with the catalyst of the comparative example, the catalysts of the respective examples exhibited greater hydrogen generation amounts in a low temperature range, and it is apparent that this resulted from the fact that the $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid-solution powders were used. Moreover, compared with the catalysts of Example No. 2 and Example No. 3, the catalysts of Example No. 1 and Example No. 4 exhibited lower hydrogen generation amounts, and accordingly it is understood that an optimum value exists between 1 to 30% by mol in the Al_2O_3 content in the $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid solution.

(Example No. 5)

[0076] With respect to a predetermined amount of a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid-solution powder which included Al_2O_3 in an amount of 1% by mol, a rhodium nitrate aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was dried at 250 °C for 15 minutes, and was thereafter calcined at 500 °C for 30 minutes to load Rh. The loading amount of Rh was 1% by weight.

[0077] While, with respect to a predetermined amount of a $\gamma\text{-Al}_2\text{O}_3$ powder, a platinum dinitrodiammine aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was dried at 250 °C for 15 minutes, and was thereafter calcined at 500 °C for 30 minutes to load Pt. The loading amount of Pt was 2% by weight.

[0078] 50 parts by weight of the $\text{Rh/ZrO}_2\text{-Al}_2\text{O}_3$ powder and 100 parts by weight of the $\text{Pt/Al}_2\text{O}_3$ powder, which were obtained in the aforementioned manner, were mixed, and were further mixed with an alumina sol and water to prepare a slurry. Then, a honeycomb substrate (abbreviated as "TP" in the drawing), which had a diameter of 30 mm and a length of 50 mm and which was made from cordierite, was immersed into this slurry, and was thereafter taken up therefrom. An excessive slurry was removed by suction, and the slurry was dried and calcined to form a coating layer. The coating layer was 150 g with respect to 1 L of the honeycomb substrate, and Pt was loaded in an amount of 2 g and Rh was loaded in an amount of 0.5 g with respect to 1 L of the honeycomb substrate.

[0079] Then, into the honeycomb substrate with the coating layer formed, a potassium nitrate aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was evaporated, and was dried to solidify. Thereafter, it was dried at 250 °C, and was calcined at 500 °C for 30 minutes to load K. The loading amount of K was 0.2 mol with respect to 1 L of the honeycomb substrate.

(Comparative Example No. 2)

[0080] 50 parts by weight of a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid-solution powder, which was the same as that of Example No. 5, and 100 parts by weight of a $\gamma\text{-Al}_2\text{O}_3$ powder, were mixed, and were further mixed with an alumina sol and water to prepare a slurry. Then, by using this slurry, a coating layer was formed in the same manner as Example No. 5.

[0081] Next, into the honeycomb substrate with the coating layer formed, a platinum dinitrodiammine aqueous solution, which had a predetermined concentration, was absorbed, was evaporated, and was dried to solidify. Thereafter, it was calcined at 300 °C for 15 minutes to load Pt. Subsequently, a rhodium nitrate aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was evaporated, and was dried to solidify. Thereafter, it was calcined at 300 °C for 15 minutes to load Rh. The respective loading amounts were 2 g for Pt and 0.5 g for Rh with respect to 1 L of the honeycomb substrate.

[0082] Thereafter, a potassium nitrate aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was evaporated, and was dried to solidify. Thereafter, it was dried at 250 °C, and was calcined at 500 °C for 30 minutes to load K. The loading amount of K was 0.2 mol with respect to 1 L of the honeycomb substrate.

(Comparative Example No. 3)

[0083] With respect to a predetermined amount of a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid-solution powder, which was the same as that of Example No. 5, a platinum dinitrodiammine aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was dried at 250 °C for 15 minutes, and was thereafter dried at 500 °C for 30 minutes to load Pt. The loading amount of Pt was 2% by weight.

[0084] While, with respect to a predetermined amount of a $\gamma\text{-Al}_2\text{O}_3$ powder, a rhodium nitrate aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was dried at 250 °C for 15 minutes, and was thereafter calcined at 500 °C for 30 minutes to load Rh. The loading amount of Rh was 1% by weight.

[0085] 100 parts by weight of the $\text{Pt/ZrO}_2\text{-Al}_2\text{O}_3$ powder and 50 parts by weight of the $\text{Rh/Al}_2\text{O}_3$ powder, which were obtained in the aforementioned manner, were mixed, and were further mixed with an alumina sol and water to prepare a slurry. Then, by using this slurry, a coating layer was formed in the same manner as Example No. 5. The coating layer was 150 g with respect to 1 L of the honeycomb substrate, and Pt was loaded in an amount of 2 g and Rh was loaded in an amount of 0.5 g with respect to 1 L of the honeycomb substrate.

[0086] Then, into the honeycomb substrate with the coating layer formed, a potassium nitrate aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was evaporated, and was dried to solidify. Thereafter, it was dried at 250 °C, and was calcined at 500 °C for 30 minutes to load K. The loading amount of K was 0.2 mol with respect to 1 L of the honeycomb substrate.

(Comparative Example No. 4)

[0087] With respect to a predetermined amount of a ZrO_2 powder, which was the same as that of Comparative Example No. 1, a rhodium nitrate aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was dried at 250 °C for 15 minutes, and was thereafter calcined at 500 °C for 30 minutes to load Rh. The loading amount of Rh was 1% by weight.

[0088] While, with respect to a predetermined amount of a $\gamma\text{-Al}_2\text{O}_3$ powder, a platinum dinitrodiammine aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was dried at 250 °C for 15 minutes, and was thereafter calcined at 500 °C for 30 minutes to load Pt. The loading amount of Pt was 2% by weight.

[0089] 50 parts by weight of the Rh/ ZrO_2 powder and 100 parts by weight of the Pt/ Al_2O_3 powder, which were obtained in the aforementioned manner, were mixed, and were further mixed with an alumina sol and water to prepare a slurry. By using this slurry, a coating layer was formed in the same manner as Example No. 5. The coating layer was 150 g with respect to 1 L of the honeycomb substrate, and Pt was loaded in an amount of 2 g and Rh was loaded in an amount of 0.5 g with respect to 1 L of the honeycomb substrate.

[0090] Then, into the honeycomb substrate with the coating layer formed, a potassium nitrate aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount, was evaporated, and was dried to solidify. Thereafter, it was dried at 250 °C, and was calcined at 500 °C for 30 minutes to load K. The loading amount of K was 0.2 mol with respect to 1 L of the honeycomb substrate.

<Testing and Evaluation>

[0091] The respective catalysts of Example No. 5 as well as Comparative Example Nos. 2 through 4 were put in an evaluating apparatus, and a durability test was carried out in which they were held at 550 °C for 3 hours in a fluctuating atmosphere in which the lean/rich model gases set forth in Table 1 were flowed for 4-minute rich model gas and for 1-minute lean gas. The total flow rate of the gases was 30 L/min.

[0092] On the respective pellet catalysts after the durability test, the saturated NO_x sorption amounts in a lean atmosphere were measured at the respective temperatures, 300 °C, 400 °C, 500 °C and 600 °C, by using model gases, which were prepared by removing SO_2 from the model gases set forth in Table 1, in a fluctuating atmosphere in which the lean/rich model gases were flowed for 4-minute rich model gas and for 1-minute lean gas. The results are illustrated in Fig. 4.

[0093] From Fig. 4, it is seen that, compared with the catalysts of Comparative Example Nos. 2 through 4, the catalyst of Example No. 5 exhibited greater saturated NO_x sorption amounts. Since the loading amounts of the respective catalytic components were identical in the catalysts of Example No. 5 as well as Comparative Example Nos. 2 through 4, the differences in the saturated NO_x sorption amounts were resulted from the fact that the loading methods were different.

[0094] Namely, in the catalyst of Comparative Example No. 2, the Pt and Rh were loaded on the Al_2O_3 and $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid solution in a uniformly dispersed manner, and, in the catalysts of Comparative Example Nos. 3 and 4, although the Pt and Rh were loaded separately, the Rh was not loaded on the $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid solution. On the other hand, in the catalyst of Example No. 5, the Pt was loaded on the Al_2O_3 , the Rh was loaded on the $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid solution. Thus, since the Pt and Rh were loaded separately, and, in addition, since hydrogen was generated at the catalytic portions, in which the Rh was loaded on the $\text{ZrO}_2\text{-Al}_2\text{O}_3$ solid solution, in a rich atmosphere, it is believed that the catalyst of Example No. 5 exhibited an extremely high NO_x sorption ability in post-durability.

Testing Sample

[0095] While stirring a zirconium oxynitrate aqueous solution having a concentration of 30% byweight, ammonia water having a concentration of 10% by weight was gradually added so that a molar ratio, $\text{Zr} : \text{NH}_3$, become 2 : 3, thereby precipitating zirconia precursors. After filtering and washing the resulting deposits, they were dried at 200 °C for 3 hours, and were calcined at 500 °C for 2 hours, thereby preparing a ZrO_2 powder. This ZrO_2 powder was mixed into distilled water, while stirring it, a predetermined amount of an aluminum nitrate aqueous solution having a concentration of 30% by weight was stirred and mixed, and ammonia water having a concentration of 10% by weight was added gradually thereto so that a molar ratio, $\text{Al} : \text{NH}_3$, become 2 : 3, thereby precipitating alumina precursors on the surface of the ZrO_2 powder. After filtering and washing the resulting deposits, they were dried at 200 °C for 3 hours, and were calcined at 500 °C for 2 hours, thereby preparing a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide powder.

[0096] In accordance with the afore mentioned manufacturing process, 4 kinds of $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide powders were prepared in which a molar ratio, $\text{ZrO}_2 : \text{Al}_2\text{O}_3$, was 99 : 1, 90 : 10, 80 : 20, 70 : 30 by fed composition.

[0097] The superficial compositions in the particles of the resulting respective $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide powders were found from the XPS peaks by calculation, and the results are illustrated in Fig. 5. In Fig. 5, the fed compositions

were illustrated as well. According to XPS, since it is possible to obtain information in a range of from the surface to a few nm's, it is seen that, in the respective $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide particles, the Al_2O_3 compositions in the range of from the surface to a few nm's were greater than the fed values. Namely, in accordance with the aforementioned manufacturing process, it is possible to manufacture first composite particles which have a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion.

(Comparative Example No. 5)

[0098] Into a 50 g of a commercially available ZrO_2 powder, a rhodium nitrate aqueous solution, which had a predetermined concentration, was impregnated in a predetermined amount, and was evaporated, and was dried to solidify. Thereafter, it was calcined at 500 °C for 1 hour, thereby preparing an Rh/ ZrO_2 catalyst powder in which Rh was loaded in an amount of 1% by weight.

[0099] While, a predetermined amount of a zirconium oxynitrate aqueous solution having a concentration of 30% by weight and a predetermined amount of a titanium chloride aqueous solution having a concentration of 30% by weight were stirred to mix, and ammonium aqueous solution having a concentration of 10% by weight was gradually added thereto so that a molar ratio, $(\text{Zr} + \text{Ti}) : \text{NH}_3$, become 2 : 3, thereby co-precipitating oxide precursors. After filtering and washing the resulting deposits, they were dried at 200 °C for 3 hours, and were calcined at 500 °C for 2 hours, thereby preparing a $\text{ZrO}_2\text{-TiO}_2$ composite oxide powder. This $\text{ZrO}_2\text{-TiO}_2$ composite oxide powder had a uniform composition from the inside to the superficial portion, ZrO_2 was 70% by weight, and TiO_2 was 30% by weight. Moreover, the average particle diameter was 5 μm .

[0100] Subsequently, the total amount of the aforementioned Rh/ ZrO_2 catalyst powder, 100 g of the $\text{ZrO}_2\text{-TiO}_2$ composite oxide powder and 100 g of an Al_2O_3 powder were mixed, and were further mixed with an alumina sol and water to prepare a slurry. Then, a 35-cc honeycomb substrate (abbreviated as "TP" in the drawing) was prepared, was immersed into this slurry, and was thereafter taken up therefrom. An excessive slurry was removed by suction, the slurry was dried at 200 °C for 3 hours, and was thereafter calcined to form a coating layer. The coating layer was 250 g with respect to 1 L of the honeycomb substrate, and Rh was loaded in an amount of 0.5 g with respect to 1 L of the honeycomb substrate.

[0101] Then, into the honeycomb substrate with the coating layer formed, a platinum dinitrodiammine aqueous solution, which had a predetermined concentration, was absorbed in a predetermined amount. The loading amount of Pt was 2 g with respect to 1 L of the honeycomb substrate. Moreover, by using a potassium nitrate aqueous solution and barium acetate aqueous solution, which had predetermined concentrations, Ba and K were loaded similarly. The loading amounts of Ba and K were 0.2 mol and 0.15 mol, respectively, with respect to 1 L of the honeycomb substrate.

(Comparative Example No. 6)

[0102] While stirring azirconium oxynitrate aqueous solution having a concentration of 30% by weight, ammonia water having a concentration of 10% by weight was gradually added so that a molar ratio, $\text{Zr} : \text{NH}_3$, become 2 : 3, thereby precipitating zirconia precursors. After filtering and washing the resulting deposits, they were dried at 200 °C for 3 hours, and were calcined at 500 °C for 2 hours, thereby preparing a ZrO_2 powder. This ZrO_2 powder was mixed into distilled water, while stirring it, a titanium chloride aqueous solution having a concentration of 30% by weight was added in a predetermined amount, and thereafter ammonia water having a concentration of 10% by weight was gradually added so that a molar ratio, $\text{Ti} : \text{NH}_3$, become 2 : 3, thereby precipitating titania precursors on the surface of the ZrO_2 powder. After filtering and washing the resulting deposits, they were dried at 200 °C for 3 hours, and were calcined at 500 °C for 2 hours, thereby preparing a $\text{ZrO}_2\text{-TiO}_2$ composite oxide powder. This $\text{ZrO}_2\text{-TiO}_2$ composite oxide powder had an average particle diameter of 5 μm , and was made into a second composite particle structure, which had a structure comprising a core portion in which ZrO_2 was a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion. The fed compositions were 70% by weight for ZrO_2 and 30% by weight for TiO_2 .

[0103] Except that the powder comprising the second composite particles, which had a structure comprising a core portion in which ZrO_2 was a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion, was used instead of the $\text{ZrO}_2\text{-TiO}_2$ composite oxide powder, which was uniform from the inside to the superficial portion, a catalyst of Comparative Example No. 6 was prepared in the same manner as Comparative Example No. 5.

(Example No. 6)

[0104] While stirring azirconium oxynitrate aqueous solution having a concentration of 30% by weight, ammonia

water having a concentration of 10% by weight was gradually added so that a molar ratio, $\text{Zr} : \text{NH}_3$, become 2 : 3, thereby precipitating zirconia precursors. After filtering and washing the resulting deposits, they were dried at 200°C for 3 hours, and were calcined at 500 °C for 2 hours, thereby preparing a ZrO_2 powder. This ZrO_2 powder was mixed into distilled water, while stirring it, an aluminum nitrate aqueous solution having a concentration of 30% by weight was added in a predetermined amount by stirring, and ammonia water having a concentration of 10% by weight was gradually added thereto so that a molar ratio, $\text{Al} : \text{NH}_3$, become 2 : 3, thereby precipitating alumina precursors on the surface of the ZrO_2 powder. After filtering and washing the resulting deposits, they were dried at 200°C for 3 hours, and were calcined at 500 °C for 2 hours, thereby preparing a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide powder. This $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide powder had an average particle diameter of 5 μm , and was made into a first composite particle structure, which comprised a core portion in which ZrO_2 was a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion. The fed compositions were 90% by weight for ZrO_2 and 10% by weight for Al_2O_3 .

[0105] Except that the resulting powder comprising the first composite particles, which had a structure comprising a core portion in which ZrO_2 was a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion, was used instead of the commercially available ZrO_2 powder, an Rh/ $\text{ZrO}_2\text{-Al}_2\text{O}_3$ catalyst, in which Rh was loaded in an amount of 1% byweight, was prepared in the same manner as Comparative Example No. 5. Then, except that this Rh/ $\text{ZrO}_2\text{-Al}_2\text{O}_3$ catalyst powder was used instead of the Rh/ ZrO_2 catalyst powder, a catalyst for purifying an exhaust gas of Comparative Example No. 6 was prepared in the same manner as Example No. 6.

<Testing and Evaluation>

[0106]

TABLE 3

	H_2 %	NO ppm	C_3H_6 ppmC	CO_2 %	CO %	O_2 %	SO_2 ppm	N_2
Lean	none	800	930	7.3	none	10.5	100	balance
Rich	0.89	none	2000	11.3	3.59	none	100	balance

[0107] The respective catalysts of comparative Example Nos. 5 and 6 as well as Example No. 6 were put in an evaluating apparatus, and a durability test was carried out in which they were held at 600 °C for 4 hours in a fluctuating atmosphere in which the lean/rich model gases set forth in Table 3 were flowed for 5-second rich model gas and for 55-second lean gas. The total flow rate of the gases was 30 L/min.

[0108] On the respective catalysts after the durability test, by using model gases, which were prepared by removing SO_2 from the model gases set forth in Table 1, the rich gas was flowed for 3 seconds in the middle of flowing the lean gas, and the NO_x sorption amounts thereafter (Post-rich Spiking NO_x Sorption Amounts = RS Sorption Amounts) were measured at the respective temperatures between 250 and 500°C. The results are illustrated in Fig. 6.

[0109] From Fig. 6, compared with the catalyst of Comparative Example No. 5, the catalyst of Comparative Example No. 6 exhibited higher NO_x sorption amounts at the respective temperatures. It is apparent that this resulted from the fact that the second composite particles, which had a structure comprising a core portion in which ZrO_2 was a major component and a superficial portion formed on a surface of the core portion and including TiO_2 more than the core portion, was made into the support of the NO_x sorption-and-reduction type catalyst, and is believed that, in the catalyst of Comparative Example No. 6, the sulfur poisoning of the NO_x sorption members was suppressed in the time of the durability test.

[0110] Then, compared with the catalyst of Comparative Example No. 6, the catalyst of Example No. 6. exhibited much higher NO_x sorption amounts. It is apparent that this resulted from the fact that Rh was loaded on the first composite particles, which had a structure comprising a core portion in which ZrO_2 was a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion, and is believed that it is because the sulfur poisoning of Rh was suppressed in the time of the durability test and because a high hydrogen generating ability was revealed in post-durability as well.

Claims

1. A hydrogen generating catalyst characterized in that Rh is loaded on a support comprising a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide.

2. The hydrogen generating catalyst, set forth in claim 1, wherein Al_2O_3 is included in an amount of from 1 to 30% bymol in said $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide.
- 5 3. The hydrogen generating catalyst set forth in claim 1, wherein the support comprising said $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide includes first composite particles having a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including Al_2O_3 more than the core portion.
- 10 4. A catalyst for purifying an exhaust gas, of an NO_x sorption-and-reduction type catalyst comprising a noble metal and an NO_x sorption member loaded on a porous oxide support, is characterized in that said catalyst includes either of the hydrogen generating catalysts set forth in claims 1 through 3.
- 15 5. The catalyst for purifying an exhaust gas set forth in claim 4, wherein said porous oxide support includes second composite particles having a structure comprising a core portion in which ZrO_2 is a major component and a superficial portion formed on a surface of the core portion and including an oxide, whose basicity is lower than ZrO_2 , more than the core portion.
- 20 6. The catalyst for purifying an exhaust gas set forth in claim 5, wherein said oxide, whose basicity is lower than ZrO_2 , is Al_2O_3 , and said second composite particles are a $\text{ZrO}_2\text{-Al}_2\text{O}_3$ composite oxide.
- 25 7. The catalyst for purifying an exhaust gas set forth in claim 6, wherein a composition of said second composite particles falls in a range of $\text{Al}_2\text{O}_3/\text{ZrO}_2 = 3/97 - 15/85$ by molar ratio.
8. The catalyst for purifying an exhaust gas set forth in claim 5, wherein said oxide, whose basicity is lower than ZrO_2 , is TiO_2 , and said second composite particles are a $\text{ZrO}_2\text{-TiO}_2$ composite oxide.
- 30 9. The catalyst for purifying an exhaust gas set forth in claim 8, wherein TiO_2 is included in an amount of 30% by weight or more in the superficial portion of said second composite particles.
- 35 10. The catalyst for purifying an exhaust gas set forth in claim 8 or 9, wherein said second composite particles further include Al_2O_3 .
11. The catalyst for purifying an exhaust gas set forth in claim 10, wherein said Al_2O_3 is included in an amount of 10% by mol or more in said second composite particles.
- 40 12. The catalyst for purifying an exhaust gas set forth in either one of claims 5 through 11, wherein an average particle diameter of said second composite particles is 10 μm or less.
13. The catalyst for purifying an exhaust gas, set forth in either one of claims 4 through 12, comprising a mixture powder of a catalyst powder, in which Pt and an NO_x sorption member are loaded on said porous oxide support, and a powder of either one of the hydrogen generating catalysts set forth in either one of claims 1 through 3.
- 45 14. The catalyst for purifying an exhaust gas, set forth in either one of claims 4 through 12, including a catalyst powder in which a noble metal and an NO_x sorption member are loaded on a mixture powder of a powder comprising said porous oxide support and a powder of either one of the hydrogen generating catalysts set forth in claims 1 through 3.

FIG. 1

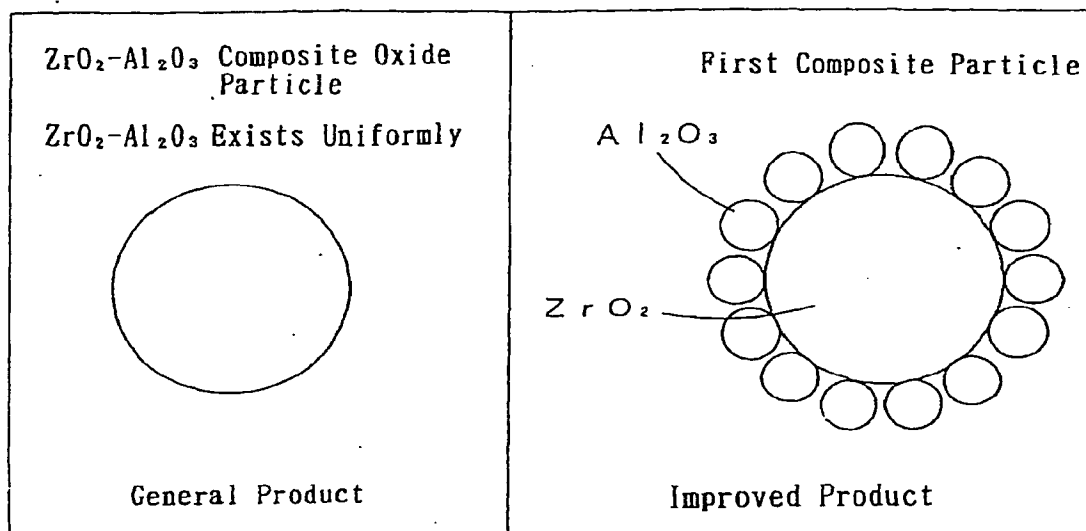


FIG. 2

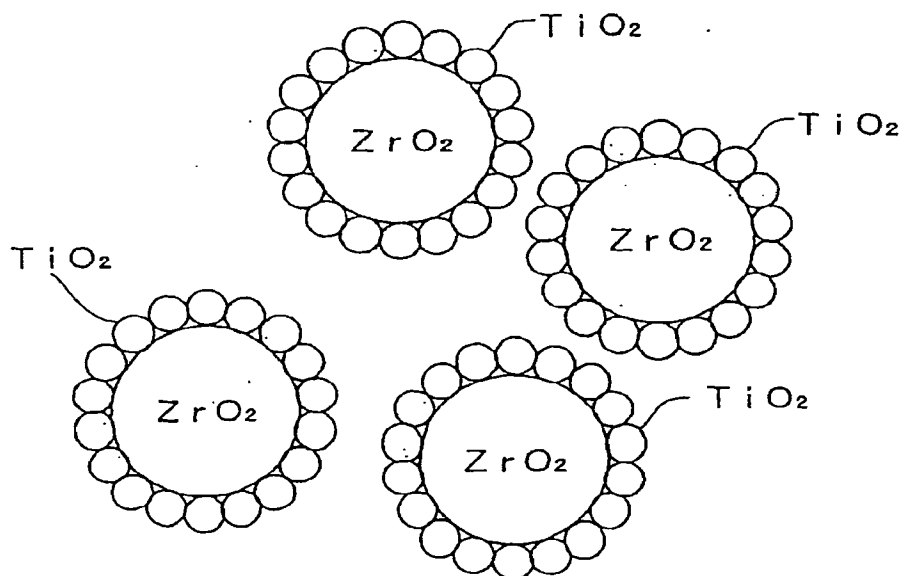


FIG. 3

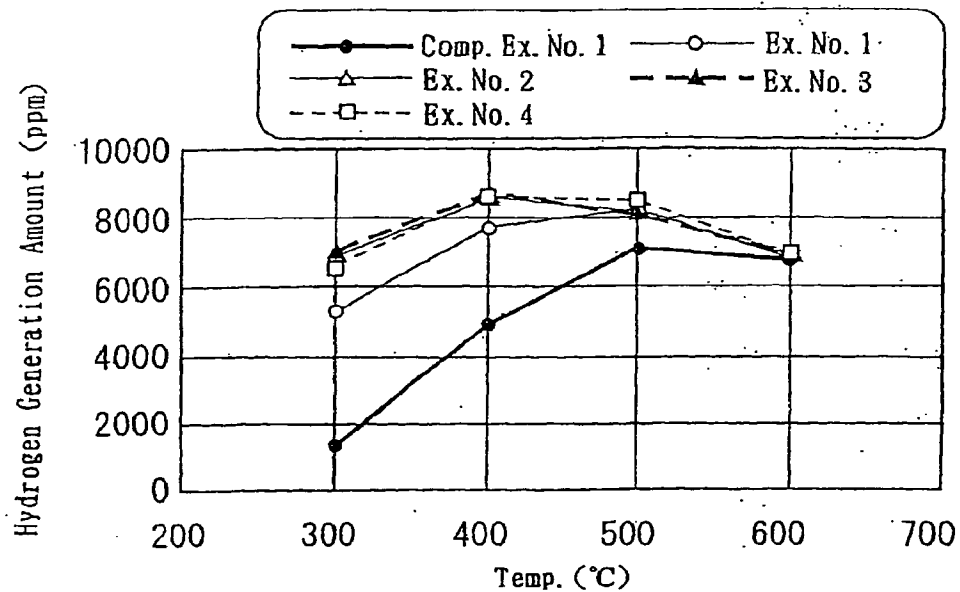


FIG. 4

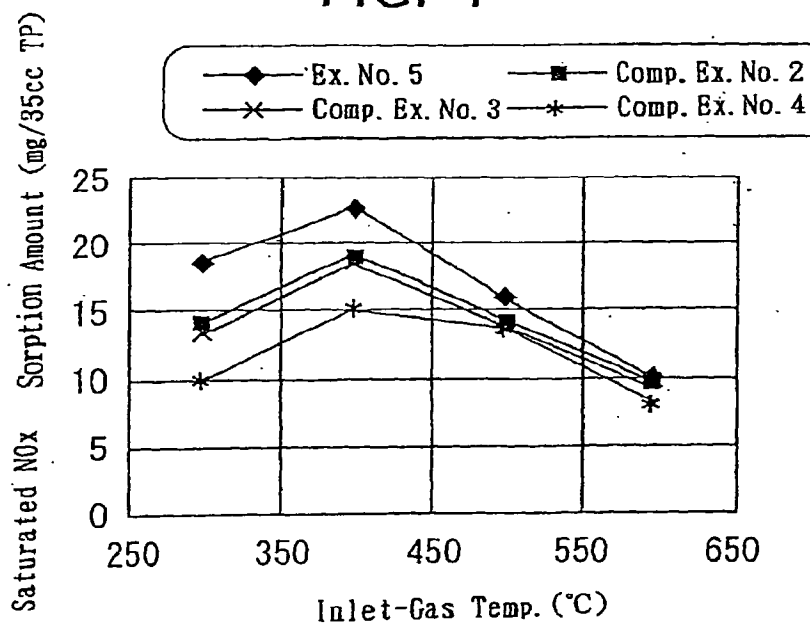


FIG. 5

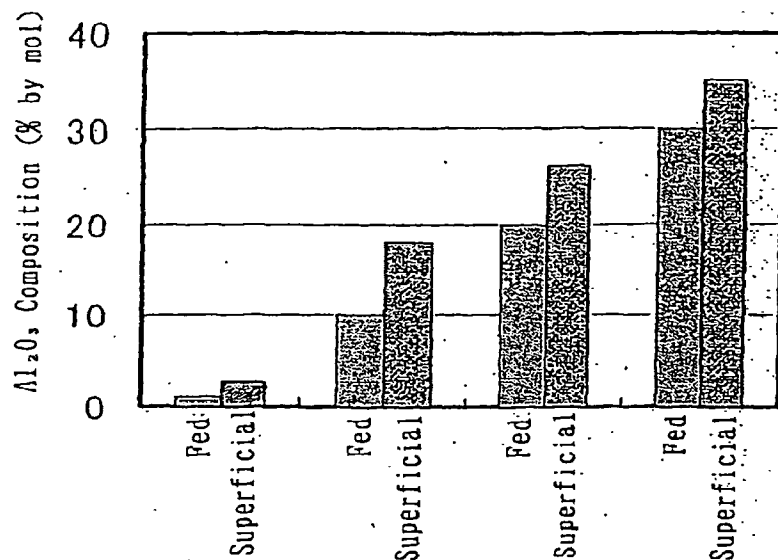
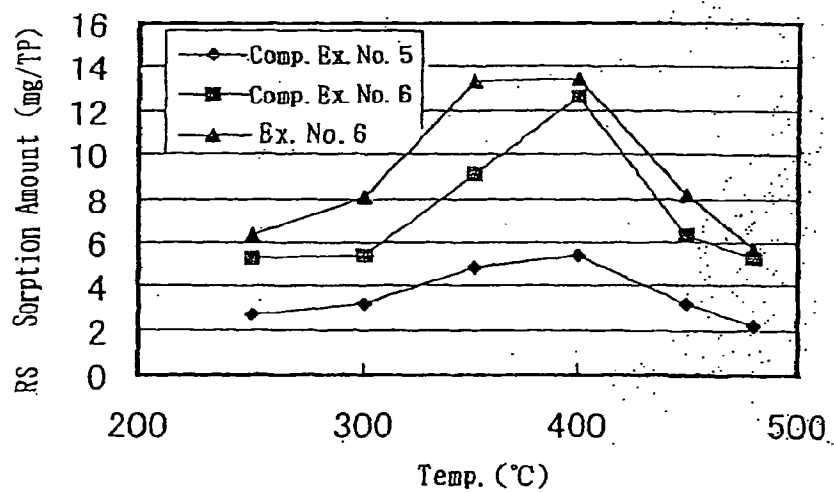


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP02/00901

A. CLASSIFICATION OF SUBJECT MATTER		
Int.Cl ⁷ B01J23/46, B01J23/58, B01D53/94		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
Int.Cl ⁷ B01J21/00-38/74, B01D53/86, B01D53/94		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2002 Kokai Jitsuyo Shinan Koho 1971-2002 Jitsuyo Shinan Toroku Koho 1996-2002		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
JOIS (ARUMINA*JIRUKONIA*SUIISO*HAIGASU (in Japanese))		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 852966 A1 (Toyota Jidosha K.K.),	1, 2, 4
Y	15 July, 1998 (15.07.98),	13, 14
A	Claim 1; page 4, lines 29 to 36; page 8, lines 3 to 7; page 17, line 50 to page 18, line 21 & JP 10-225636 A Claim 1; Par. Nos. [0010], [0020], [0043] to [0045] & US 6165429 A	3, 5-12
X	JP 5-168924 A (Tonen Corp.), 02 July, 1993 (02.07.93), Claim 1; Par. Nos. [0002], [0011]; examples (Family: none)	1, 2
Y	JP 10-356 A (Toyota Jidosha K.K.), 06 January, 1998 (06.01.98), Claim 1; example 1 (Family: none)	13
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 11 April, 2002 (11.04.02)		Date of mailing of the international search report 23 April, 2002 (23.04.02)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP02/00901

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2000-189798 A (Toyota Jidosha K.K.), 11 July, 2000 (11.07.00), Claim 1; examples (Family: none)	14
A	EP 707882 A1 (Toyota Jidosha K.K.), 24 April, 1996 (24.04.96), Claim 1 & JP 8-117602 A Claim 1 & US 5804152 A	3,5-12
A	EP 992276 A1 (Mazda Motor Corp.), 12 April, 2000 (12.04.00), Claim 1; Par. No. [0007] & JP 2000-102728 A Claim 1; Par. No. [0007]	3,5-12

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